

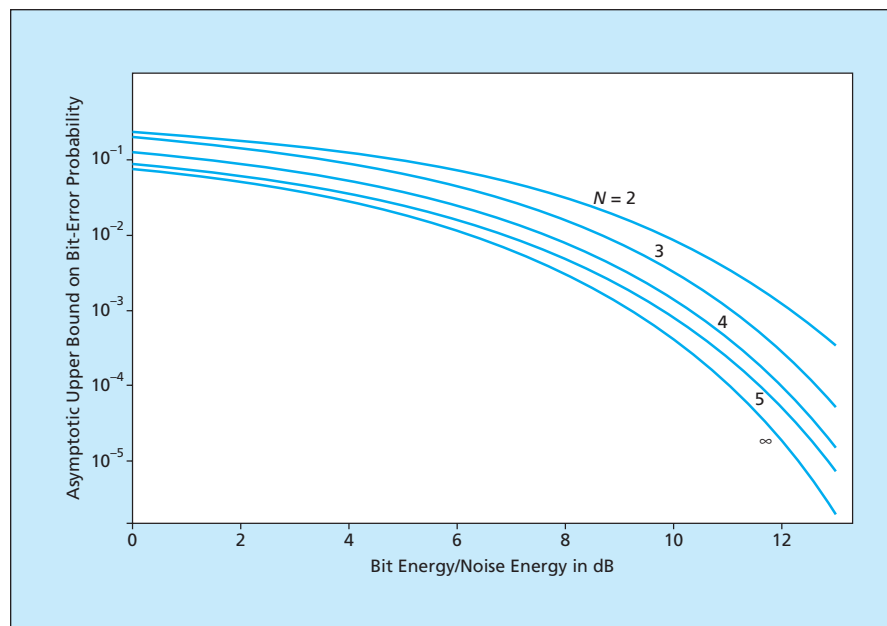
structure, first for OQPSK and then differentially encoded OQPSK. It was shown that the precoding needed to

obtain the equivalence is such as to result in a ternary (0,-1,+1) CPM input alphabet that, during any given one-bit

observation period, is equivalent to a binary alphabet. Next, some results of prior work by the same author on maximum-likelihood block detection of noncoherent CPM were utilized to derive a maximum-likelihood decision metric and an associated receiver structure for the precoded version that equivalently represents differentially encoded OQPSK.

The figure presents some results of computations of the bit-error performance of the present method. Because of its maximum-likelihood basis, this method is expected to be the most power-efficient method of differential detection of OQPSK. Furthermore, on the basis of the resemblance of this method to the prior multiple-symbol method of differential detection of non-offset QPSK, the performance of a receiver based on this method is expected to improve with increasing  $N$ .

*This work was done by Marvin Simon of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).  
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The **Asymptotic Upper Bound on the Average Bit-Error Probability** for a receiver based on the proposed method has been computed as a function of the bit-energy/noise-energy ratio and the number ( $N$ ) of bit periods in the observation time.

## Absolute Position Encoders With Vertical Image Binning

Conversion rates can exceed 20 kHz.

*Goddard Space Flight Center, Greenbelt, Maryland*

Improved optoelectronic pattern-recognition encoders that measure rotary and linear 1-dimensional positions at conversion rates (numbers of readings per unit time) exceeding 20 kHz have been invented. Heretofore, optoelectronic pattern-recognition absolute-position encoders have been limited to conversion rates <15 Hz — too low for emerging industrial applications in which conversion rates ranging from 1 kHz to as much as 100 kHz are required. The high conversion rates of the improved encoders are made possible, in part, by use of vertically compressible or binnable (as described below) scale patterns in combination with modified readout sequences of the image sensors [charge-coupled devices (CCDs)] used to read the scale patterns. The modified readout sequences and the processing of the images thus read out are amenable to implementation by use of modern, high-speed, ultra-compact microprocessors and digital signal processors or field-programmable gate arrays. This combination of improvements makes it

possible to greatly increase conversion rates through substantial reductions in all three components of conversion time: exposure time, image-readout time, and image-processing time.

In a typical prior optoelectronic pattern-recognition absolute-position encoder, the CCD is oriented with its horizontal axis parallel to the axis along

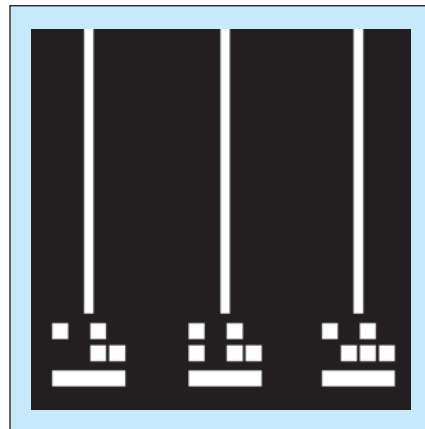


Figure 1. **Previous Patterns Contain Both Vertical and Horizontal Information** and must be read out pixel-by-pixel.

which the position of the scale pattern is to be measured. The pattern includes vertically oriented fiducial bars plus small rectangles or squares, representing code bits, that serve to uniquely identify the fiducial bars (see Figure 1). The lower limit on conversion time is determined primarily by the exposure time and the time required to read out the

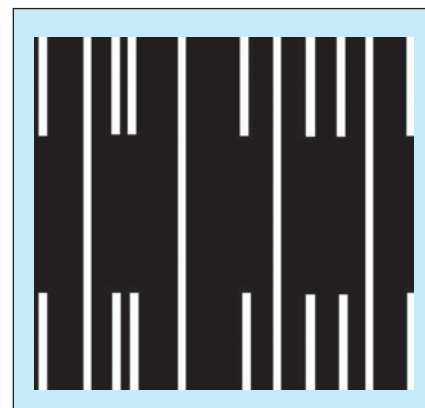


Figure 2. **Portion of New Scale Pattern**, partly resembling common bar code, is representative of vertically binnable patterns used in encoders of the type described in the text.

entire image from the CCD, pixel by pixel. The exposure time must be long enough to obtain adequate signal-to-noise ratios in the code-bit marks. The requirement for pixel-by-pixel readout of the entire image arises from the use of vertical (as well as horizontal) position information to distinguish among code-bit marks in different rows.

In conventional pixel-by-pixel readout, during each row-readout clock cycle, the signal contents of all the pixels of each row are shifted down to the next row, except that the contents of the bottom row are shifted down to a serial register, which triggers analog-to-digital conversion of each pixel's signal. Then, before the beginning of the next row-readout clock cycle, the contents of the serial register are shifted out, one pixel at a time, in response to sequence of column-readout pulses.

In vertically binned readout, which is an established alternative to conventional pixel-by-pixel readout, the sequence of clock pulses is modified so that the contents of multiple rows are shifted down to the serial register before applying the column-readout

pulses. As a result, vertical resolution is lost, but time needed for reading out the image charge from all the pixels is reduced by a factor equal to the number of rows shifted prior to shifting the column contents out of the serial register. Moreover, the image-data processes needed to extract the vertical spatial information to determine row locations of code-bit marks can be eliminated. Inasmuch as the consequent loss of vertical resolution does not adversely affect the desired measurement of horizontal position, vertical binning can thus be used to reduce readout time substantially, provided that the scale pattern is such that the horizontal spatial information in the code-bit marks suffices to uniquely identify the fiducial bars. A scale pattern that satisfies this requirement is said to be vertically binnable.

Figure 2 shows an example of a vertically binnable scale pattern. The vertical stripes spanning the entire field from top to bottom are the fiducial bars. The stripes that extend part way up from the bottom and part way down from the top are the code-bit marks. The code-bit

marks at the top and bottom are identical, so that the image can be binned by the full height (that is, all the rows can be included in the bin for each column, enabling maximum speedup). Other patterns in which code bits at top and bottom differ but identify a greater number of fiducials dramatically increase range, while still greatly speeding up readout. Among the secondary advantages of such a vertically binnable pattern is that the vertical alignment of the CCD relative to the pattern is much less critical than is the alignment needed to utilize the vertical spatial information in a conventional pattern with pixel-by-pixel readout.

*This work was done by Douglas B. Leviton of Goddard Space Flight Center. Further information is contained in a TSP (see page 1).*

*This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Goddard Space Flight Center, (301) 286-7351. Refer to GSC-14633-1.*

## Flexible, Carbon-Based Ohmic Contacts for Organic Transistors

**These contacts are printed using an inexpensive, low-temperature process.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

A low-temperature process for fabricating flexible, ohmic contacts for use in organic thin-film transistors (OTFTs) has been developed. Typical drain-source contact materials used previously for OTFTs include (1) vacuum-deposited noble-metal contacts and (2) solution-deposited intrinsically conducting molecular or polymeric contacts. Both of these approaches, however, have serious drawbacks.

Use of vacuum-deposited noble-metal contacts (such as gold or platinum) obviates one of the main benefits of organic electronics, which is low-cost processing based on solution or printing techniques. First, it requires the use of vacuum-deposition techniques (such as sputtering or evaporation) instead of the less expensive solution-based processes such as spin coating, casting, or printing. Second, the use of gold or platinum for coating large-area devices is potentially expensive (both from a standpoint of materials and processing equipment). Again, this approach runs counter to the perceived low-cost benefit of organic

electronics. Furthermore, adhesion of gold to many organic materials is very poor. Some recent work has been carried out regarding intrinsically conducting molecular- or polymeric-based contacts such as polyaniline and TTF-TCNQ. Unfortunately, these materials tend to exhibit high resistivities and poor overall performance, are prone to reaction with the surrounding environment, and are potentially unstable with time.

To achieve an ohmic contact to the organic semiconductor, the work function of the contact should be well matched to that of the semiconductor. Due to the similar chemical nature of the graphite filler to the conjugated poly(3-hexylthiophene) (P3HT) polymer, it was surmised that a carbon paste may possess a similar work function and therefore behave as suitable ohmic contact in this application.

To demonstrate the effectiveness of this approach, bottom contact thin-film transistors were fabricated (Fig. 1). A highly doped silicon wafer was

used as the substrate, with a thermally grown 300-nm oxide gate dielectric layer. In this case, a 5-mil (127- $\mu$ m) thick laser-cut stainless-steel stencil was used to pattern the contacts.

The carbon-based conductor used was a paste comprising a stable, flexible polymer binder and a conducting graphite/carbon-based filler. The

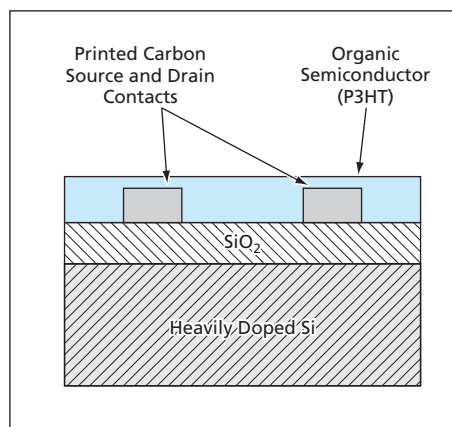


Figure 1. An **Organic Field-Effect Transistor** was fabricated in an inexpensive process, mostly at room temperature, with brief heating at 100 °C.